NON-INVASIVE CARDIOVASCULAR RISK ASSESSMENT USING HEART RATE VARIABILITY FRAGMENTATION

STATEMENT REGARDING FEDERALLY-SPONSORED RESEARCH AND DEVELOPMENT

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BACKGROUND OF THE INVENTION

Field of the Invention

[0002] Embodiments herein relate to systems and methods for assessing cardiovascular risk by fragmentation of heartbeat variability.

Background Art

[0003] Heart rate variability (HRV) is the physiological phenomenon of variation in the time interval between heartbeats for an individual. Short-term HRV is most commonly attributed to physiologic vagal tone modulation, and the degree of short-term variability of normal-to-normal (NN) sinus beats may be used as a dynamic biomarker of cardiac vagal tone modulation.

[0004] However, with aging and cardiovascular disease, the emergence of high short-term HRV, consistent with the breakdown of the neuroautonomic-electrophysiologic control system, may confound traditional HRV analysis. For example, parasympathetic regulation of sinus rhythm may decrease with aging and organic heart disease, yet the amount of short-term variability may increase for some subjects in such high risk groups.

[0005] Ultimately, the presence of abnormal variants of sinus rhythm may limit the utility of traditional HRV analysis because an increase in the overall amount of short-term variability might not be solely attributed to fluctuations in vagal tone. Therefore, a need exists for new systems, methods, and techniques for analyzing short-term HRV and distinguishing differences in the structure of fluctuations between physiologic and anomalous variability.

SUMMARY OF THE INVENTION

[0006] Example methods and systems are described herein for non-invasive cardiovascular risk assessment using a heart rate variability fragmentation approach. The degree of heartbeat fragmentation may indicate a breakdown of fluency in heartbeats resulting from aging, disease, and/or pathological conditions. In some embodiments, mathematical analysis of a change in sign of a heartbeat acceleration/deceleration signal is performed in order to measure fragmentation of heartbeats. The heartbeat comprises a speed/velocity signal, and an acceleration/deceleration represents a change in the heart rate signal. In some embodiments, the degree of heartbeat fragmentation may indicate a breakdown of fluency in heartbeats resulting from aging, disease, and/or a pathological condition.

[0007] In an embodiment, a method of assessing cardiovascular risk of a subject may include receiving a first set of electrocardiogram (ECG) signals of the subject, analyzing data from the first set of ECG signals to identify sign changes in heart rate acceleration in the first set of ECG signals, determining a degree of fragmentation in the first set of ECG signals based on the identified sign changes in heart rate acceleration, and assessing cardiovascular risk of the subject based on the degree of fragmentation. Analyzing data from the first set of ECG signals may further comprise deriving a time series of normal-to-normal (NN) interbeat intervals from each ECG signal and computing a set of fragmentation indices from the time series derived from each ECG signal. The set of fragmentation indices may be applied to the data from the first set of ECG signals.

[0008] Further features and advantages, as well as the structure and operation of various embodiments, are described in detail below with reference to the accompanying drawings. It is noted that the specific embodiments described herein are not intended to be limiting. Such embodiments are presented herein for illustrative purposes only. Additional embodiments will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein.

BRIEF DESCRIPTION OF THE DRAWINGS/FIGURES

[0009] The accompanying drawings, which are incorporated herein and form part of the specification, illustrate the present invention and, together with the description, further serve to explain the principles of the present invention and to enable a person skilled in the relevant art(s) to make and use the present invention.

[0010] FIGS. **1A-1D** illustrate examples of respiratory sinus arrhythmia and anomalous sinus rhythm, according to an embodiment of the present disclosure.

[0011] FIG. **2** illustrates a table of Spearman rank and standardized Pearson product-moment coefficients for the relationships between traditional short-term HRV, nonlinear, and fragmentation indices with cross-sectional age for the group of healthy subjects, according to an embodiment of the present disclosure.

[0012] FIG. **3** illustrates scatter plots of the traditional heart rate variability (rMSSD, pNN50 and HF), nonlinear (α_1 and SampEn (sample entropy)) and fragmentation (PIP, IALS, PSS and PAS) indices versus the participants' age for the group of healthy subjects and patients with coronary artery disease (CAD), derived from the analysis of the full (~24-hour) period, according to an embodiment of the present disclosure.

[0013] FIG. **4** illustrates a table of measured values of heart rate variability in healthy subjects and measured values of heart rate variability of subjects with coronary artery disease (CAD), according to an embodiment of the present disclosure.

[0014] FIG. **5** illustrates a table of values obtained from logistic regression analysis and area under the ROC curve for unadjusted models of CAD, according to an embodiment of the present disclosure.

[0015] FIG. **6** illustrates normalized histograms of the traditional heart rate variability (rMSSD, pNN50 and HF), nonlinear (α_1 and SampEn) and fragmentation (PIP, IALS, PSS and PAS) indices for the groups of healthy subjects (blue) and patients with coronary artery disease (red), for the 24-hour period, according to an embodiment of the present disclosure.